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A MANUAL OF PROCEDURES FOR CONDUCTING A WASTEWATER ASSIMILATION STUDY

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Ministry of the Environment

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George A. Kerr, Q.C.,
Minister

Everett Biggs,
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A MANUAL OF PROCEDURES FOR CONDUCTING A WASTEWATER ASSIMILATION STUDY

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1. GENERAL STRATEGIES

Wastewater assimilation capacity

Every river has the capability of accepting a certain amount of oxygen-demanding polluting materials and changing these materials to a non-polluting form (through the use of atmospheric and entrained oxygen) without impairing the intrinsic value of the watercourse. This ability to cleanse itself of waste is called the wastewater assimilation capability of a river. The capacity of the river to accept wastes without lowering the dissolved oxygen below a predetermined level is called the assimilative capacity of the stream.

The strategies presented in this document will deal specifically with planning and executing wastewater assimilation studies, however, many methods will be applicable to any water quality investigation.

This document should be used in conjunction with the Water Quality Stream Modelling Seminar Handbook (Water Modelling Section, Water Resources Branch, May 13, 1975).

1.1 DEFINING PROBLEM AND OBJECTIVES

Define problems and objectives

Before any field work is carried out on a stream, the problem(s) should first be defined, and the objective(s) of the study laid out. Preliminary office and field work is often necessary to define the extent of the problem, and determine how the stream reacts to waste loadings before detailed field studies can be planned and carried out.

1.2 PRELIMINARY OFFICE PLANNING

Maps of the survey area[1] should be obtained, as well as any previous reports on the waterbody and municipal and/or industrial discharges. Municipal and Private Abatement and Industrial Abatement staff can often be of assistance in this task. Pinpoint all discharges to the waterbody on the map.

Maps
reports
MOE staff

All existing data on water quality monitoring, streamflow, water takings and consumption, water uses, and volumes and characteristics of waste discharges should be obtained. In addition to MOE staff, local conservation authorities and municipal officials can usually supply a great deal of useful information.

Previous data

1.3 PRELIMINARY FIELD STUDIES

If manpower and time permit, the entire reach of stream to be studied should be inspected. Waste discharges, dispersion patterns of effluents and tributaries, physical characteristics of the stream (depth, width, water velocity, type of substrate), water uses, algal growths, the presence of benthic deposits of organic sludges and any other pertinent characteristics should be noted.

Note all physical information

One source of information, in the field that should not be overlooked is local residents, especially old-timers, who can readily provide information that may otherwise have taken a great deal of time to collect. (e.g. fishery, changes in water quality over the years etc).

[1] See Section 2.1 - Maps and Aerial Photographs

Preliminary chemical data (BOD_5, nutrients, day and night-time D.O.) should be obtained to determine the length of stream to be studied, expected concentrations of chemical parameters, and whether night-time sampling is necessary (i.e. if a diurnal-nocturnal DO variation is evident or if waste loads vary from day to night). This data should be collected far enough in advance of the proposed intensive survey date to allow for the lab analyses to be completed and evaluated.

Preliminary chemical and DO data

Based on the preliminary information sampling stations can be selected[1]. Times of travel (ToT) should be determined between sampling stations,[2] also noting times to waste inputs and tributary confluences. Observations should be made at three or more different stream flow stages over a suitable range from low flow to average summer flows and data plotted on log-log graph paper (Times of Travel vs Streamflow) which will permit interpolation or limited extrapolation for the streamflow conditions to be modelled.

Select stations
Time of travel
ToT vs flow graphs

Mixing studies should be carried out on waste discharges and tributary inflows to determine if lateral and/or vertical multi-point sampling is necessary at any downstream stations where complete mixing of the inflows with the stream water has not occured.

Mixing studies

Stream cross-sections[3] should be obtained at about 1000 ft. intervals and at those points where the physical character of the stream changes significantly. These data will be used for calculating reaeration coefficients (k_a or k_2) of the stream.[4]

Cross-sections

[1] See Section 2.2 - Station Selection
[2] See Section 2.5 - Time of Travel Studies
[3] See Section 2.3 - Stream Cross-sections
[4] See Chapter 4 - Preliminary Data Compilation

Staff gauge

At each sampling location, a staff gauge or other stage measuring device (e.g. bench mark) should be installed. Each time the station is visited the gauge height and date should be recorded to develop a gauge height vs flow curve[1] to provide stage height at any flow. This information is necessary to relate cross-sectional data to survey conditions and low flow conditions.

Low Flow
Extrapolate to low flow conditions

The low flow to be used in the loading designs must be determined or obtained from a hydrologist. The standard design streamflow for continuous discharge to a stream used by the M.O.E. has traditionally been the 20 year, 7 day low flow, 95% chance of exceedence ($7Q_{20}$). Physical data affected by streamflow, such as depth, ToT, mixing, etc., must be extrapolated to this flow. If these physical data are obtained at a flow much greater than the low-flow then extrapolation to low flow conditions is difficult. It is also important to conduct assimilation studies under flow conditions as close as possible to low flow so extrapolation of data to design conditions (low flow) will be minimal.

Benthic deposits

Where benthic deposits are believed to exert an appreciable demand on the oxygen resources of the stream, benthic respiration[2] studies should be carried out. The rate thus established will be used as a sink in the dissolved oxygen balance equation.

[1] Flows may be obtained by streamflow gauging or may be extrapolated by drainage area ratios from a nearby gauge on the same river

[2] See Section on Benthic Respiration Studies

1.4 PRE-INTENSIVE SURVEY PLANNING

Select type of study "Round-the-clock" sampling

Based on the preliminary data and the objectives of the study, the type of survey to be conducted will be determined. If 24 hour dissolved oxygen concentrations fluctuate greatly or if wastewater loadings or streamflows fluctuate greatly, then "round-the clock" sampling will be necessary. However, if streamflows and waste loadings are stable and dissolved oxygen concentrations do not fluctuate greatly (i.e. more than 2 mg/l) from day to night then a simple water quality study with limited sampling may be sufficient (enough samples should be taken, however, to provide statistically valid data[1]).

Number of samples

Once the type and scope of the study has been determined, the number of samples that will be submitted to the laboratories can be determined. Parameters that must be measured during an assimilation study are:

Parameters

- dissolved oxygen (DO) and temperature
- 5 Day Biochemical Oxygen Demand (BOD_5)
- total phosphorus
- soluble reactive phosphorus
- filtered ammonium nitrogen
- total kjeldahl nitrogen
- nitrite nitrogen
- nitrate nitrogen
- 20 day BOD[2]
- plus any other waste component that may affect water quality and use such as heavy metals or volatile suspended solids (to determine k_r rate if effluent contains high levels of suspended solids).

[1] A minimum of 12 samples will provide statistically valid data

[2] See Section 3.4 - 20 day BOD

A tentative survey date must now be selected when streamflow conditions should be low and water temperatures high (mid-July to early September). This date should be verified with all participating personnel and the laboratories. At this time the laboratories will need to know the number of samples expected and parameters requested. STP operators and/or industrial contacts must be informed of the expected date of the survey and access to their plants should be arranged for sampling personnel. A contact at this time ensures that the survey is not planned during atypical conditions (i.e. holidays or other plant shut-down periods).

Survey date
Notify labs of study
Notify operators

Availability of equipment required for the survey should be checked and sampling bottles ordered from the lab.

Equipment and bottles

Survey headquarters should be established, whether it be a local MOE office, the local STP or a motel. Motel accommodations should be arranged well in advance.

Survey headquarters
Motel accomodations

A few days before the survey, the local police departments, the OPP, the local conservation authority and municipal offices should be informed of survey plans. If dye is to be used in the river during the study, these same agencies should be informed. Regional and district MOE staff must also be informed of the survey.

Notify authorities of study

Sample transportation[1] to the MOE labs must also be arranged.

Sample transport

[1] See Section 2.6 - Sample Transportation

Maps
Notebooks

It is very important that proper maps be prepared with sampling locations and routes clearly marked. A book should be prepared in which all field data will be entered by the sample collector[1].

Staff duties

Staff must be briefed on their duties prior to the survey to ensure they know the route (take them over it prior to the survey), their duties, the bottle labelling system[2] and the work shifts[3].

Equipment and supplies check

Finally, a check should be made to ensure that all equipment is in proper working order (it is a good idea to have spare equipment available if possible) and that all supplies necessary for the study have been procured (chemicals for Winkler kits, bottles, ice chests, dye, pens and pencils, books etc).

1.5 THE FIELD SURVEY

Duration of survey

The culmination of the preliminary field work and the office planning is a well-executed field survey. This survey generally extends for 30 to 60 hours with samples collected at selected time intervals (generally 3 to 6 hours apart depending on manpower, equipment and time constraints). The duration of the survey depends upon various factors such as:

a) manpower constraints
b) laboratory capabilities
c) if P & R modelling[4] will be attempted
d) time constraints
e) length of time for sampling run

[1] See Section 2.7 - Survey Notes

[2] See Section 2.8 - Sample Numbering

[3] for around-the-clock sampling 12-hour shifts are preferable

[4] Photosynthesis and Respiration Modelling - for a complete explanation of P & R modelling refer to the Water Quality Stream Modelling Seminar Handbook (Water Modelling Section, Water Resource Branch, May 1975)

Discreet or composite sampling P & R modelling

Enough samples must be collected to provide statistical validity to the data (generally 10 to 12 samples at each station). If discreet sampling cannot be carried out, composite samples may be collected; however, only one value is obtained in this manner and the validity of this one value may be questionable, especially if a bad sample is obtained for any reason (e.g. slug discharge) during the sampling cycle. If P & R modelling is to be attempted enough DO data must be collected to provide a representative diurnal-nocturnal DO curve for about a 30 hour period from before sunrise to after sunrise the following day. The DO model is calibrated for the period sunrise to sunrise but DO data is required at each station prior to sunrise for input to the computer model.

36-hr study
48-hr study
60-hr study

If sampling runs can be conducted every 3 hours, then 12 samples can be collected during a 36-hour period providing statistically valid data and adequate DO data for modelling. The study could be conducted from 9 P.M. one day to 9 A.M. two days hence, to obtain the proper DO curve. If time constraints dictate sampling every 4 hours, then a 48-hour study should be conducted. Timing of the beginning of a 48 hour survey is not too critical as only one complete 30-hr. DO cycle can be obtained. However, if data is collected at intervals greater than 4 hours it is difficult to obtain a good diurnal-nocturnal DO graph because the points are too far apart and the high and low DO values for the day may be missed entirely. A 60 hour study with 4 hour sampling intervals will provide 15 samples and if started at 9 P.M. and finished at 9 A.M., 60 hours later, will provide two complete diurnal-nocturnal cycles for modelling needs.

Figure 1.1 illustrates survey timing to optimize the DO data collected for a 36-hour and a 60-hour study. In any event a survey should not be started or ended at a critical low point on the DO graph (i.e. early morning - 4 AM to 8 AM).

Cancelling survey

Situations may arise which may force cancellation of a study. Among them are:

- overcast weather - if survey had been planned to obtain data during hot, dry weather, then overcast weather will change DO curve.

- streamflow changes (including rain) - concentrations of parameters change greatly during a rainfall, especially during the first ½ hour of the rain.

- abnormal changes in waste loading - waste loadings are averaged over the survey period; large changes in loads result in changes of concentrations of parameters in the stream during the survey.

These three situations result in changes in the "steady-state" conditions which are desirable for ease of modelling.

Cancellation of surveys because of these conditions may be minimized by:

Check weather forcast

1) checking with the weather bureau prior to conducting the study. If overcast weather or precipitation is forcast and you do not wish to collect data during an overcast period reschedule the survey. If the survey is partially completed and the skies become overcast, DO levels will be affected and modelling will be difficult. If good DO data has been collected for the required 30 hour period prior to the overcast period then the

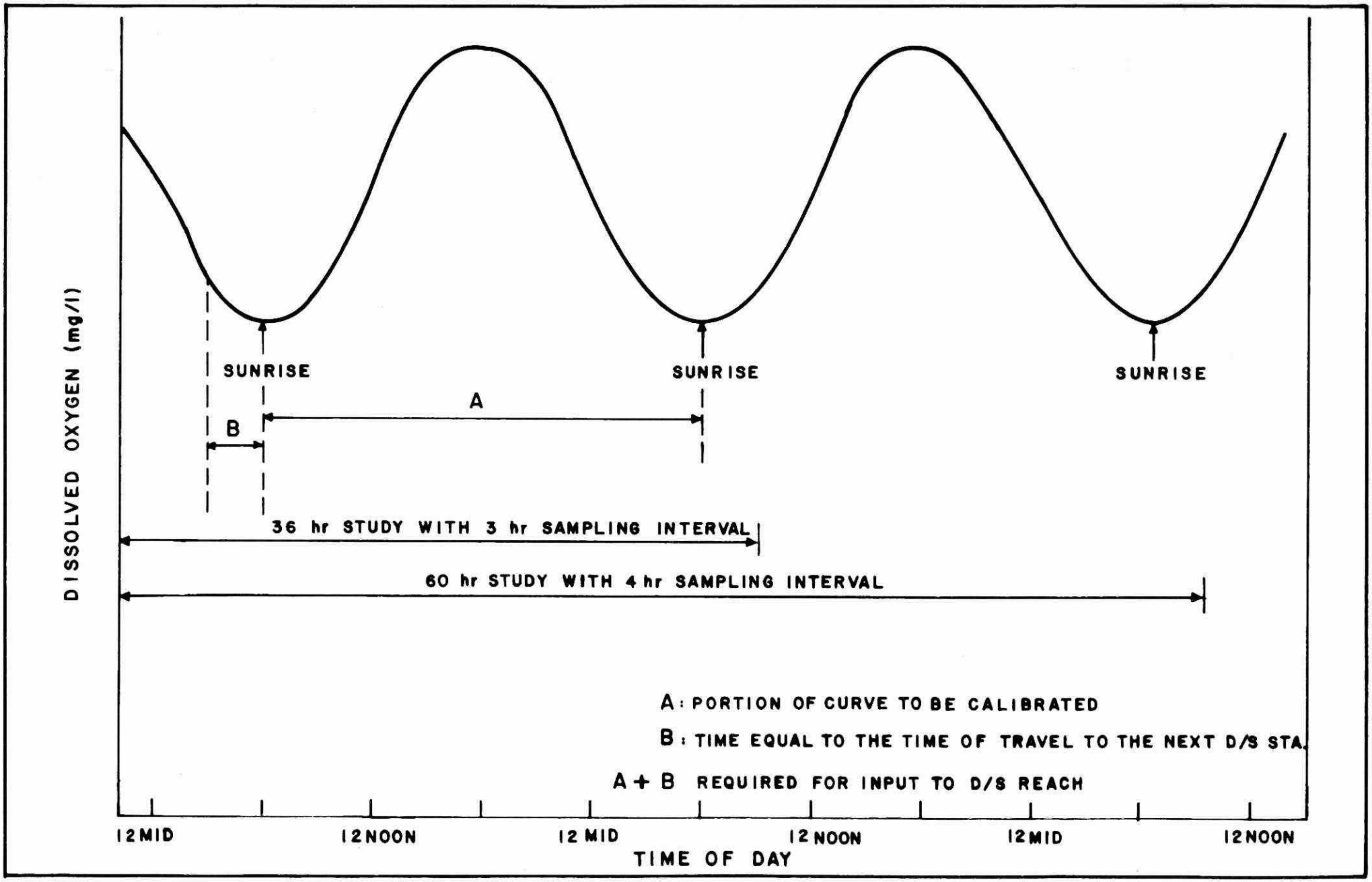

FIGURE 1·1 — STUDY TIMING AS ILLUSTRATED BY TYPICAL DIURNAL NOCTURNAL D. O. CURVE

survey may be ended rather than cancelled or postponed. However, data collected during overcast weather may be valuable as in a stream where there are algal growths, lowest DO levels will occur prior to runrise of the morning following an overcast day.

2) arranging with the proper authorities if streamflow is controlled by dams to ensure steady streamflows for the period of the survey. Rain also changes streamflows and water quality, especially in urbanized areas where storm sewers may discharge large quantities of contaminants into a river during the early portion of a storm.

Control by dams
Effect of rain

3) arranging with the STP or Industrial Plant operator to attempt to ensure that atypical loading conditions do not prevail during the study, due to construction, plant or equipment breakdown etc.

Typical waste loadings

Duties and manpower required to carry out an assimilation study are:

Personnel duties

- day sampling - one man and vehicle per route
- night sampling - two men[1] and 1 vehicle per route[2]
- time of travel[3] - one man and 1 vehicle
- co-ordinator[4] - one man and 1 vehicle
- sample transport[5] - one man and 1 vehicle
- flows[6] by velocity measurement (if necessary) two men and 1 vehicle

[1] for safety and ease of working

[2] same vehicles as day shift if MOE vehicles

[3] may be deleted if graphs have been prepared

[4] co-ordinator may perform other tasks if manpower is limited

[5] may be carried out by time of travel man if distance to labs is not too great

[6] flows may be taken by time of travel crew (two men)

Some pointers for carrying out an intensive survey are:

- DO meters should be calibrated to a Winkler titration before each run to ensure accuracy of data. Meters should be calibrated to DO levels in the same range as those expected to be measured.

Calibrate DO meters

- recording DO/temperature meters and/or automatic samplers should be installed prior to the start of the survey.

Install DO/Temp recorders and automatic samples

- Care should be taken when installing recording DO meters in the stream to ensure that water is moving past the probe with a velocity of at least 1 cm per second to prevent oxygen depletion at the membrane.

Avoid stagnant water areas

- DO recorders should be calibrated and automatic samplers checked at least once per day. Samples should be removed from the sampler at least once per day as levels of non-conservative parameters may change with time and temperature.

Check automatic equipment

- samples at each location should be collected at least 12 times during the survey (tributaries may not need to be sampled as often). This number of samples should provide statistical reliability to the data.

Sampling interval

- DO readings should be taken no more than 4 hours apart to provide a smooth representative DO graph.

DO intervals

- data should be recorded on field data cards (e.g. Fig. 2.2 a & b) and any observation out of the ordinary should be noted on the cards (e.g. turbid discharge, rainfall, etc.).

Record data

- laboratory submission sheets should be completed at the end of each sampling run to avoid confusion and a back-log of samples with no lab sheets.

Lab submission sheets

- samples should be iced and transported to the laboratory as soon as possible after sampling to ensure accurate data on perishable samples (transport samples at least once per day).

Sample transport

- time of travel data should be collected during the survey. If graphs of ToT vs flow have been previously drawn up and encompass the flow regime at the time of the study and if manpower is limited, this function may be eliminated.

Time of travel

- bottles may be prelabelled if there are not too many stations or samples to obtain; however, this practice can lead to confusion, especially if the samples are put in the wrong bottles.

Pre-labelling bottles

- the survey co-ordinator should be available for consultation any time of the day or night during the intensive survey. Portable radios may prove valuable in maintaining communication with crews. Another possible method is to rent a portable paging system i.e. Page Boy. (approximate cost $30 per month)

Survey Co-ordinator Communication

- data should be reviewed as it is collected and changes made to plans if the data warrants such changes (e.g. re-locating stations, changing sampling frequency etc.).

Review data

2. SURVEY PROCEDURES

2.1 MAPS AND AERIAL PHOTOGRAPHS

Before carrying out any work on the study, the best possible maps of the area should be obtained. Depending on the area of the Province, one or more of the following maps may be available:

Types of maps

topographical - 1:25,000 (2½ in. = one mile)
- 1:50,000 (1¼ in. = one mile)
- 1:100,000 (5/8 in. = one mile)

MTC - County - 1:250,000 (1/4 in. = one mile)

FRI maps

MNR Forest Resources Inventory (FRI) Base maps (scale 4 inches = 1 mile) are very useful for accurate river mileages. They may be obtained from Room 6404, Whitney Block, Queen's Park, Toronto.

Aerial photographs

In addition to maps, most of the Province has been covered by aerial photography. A look at the photographs of the area in stereo will sometimes show access points in areas that were previously considered inaccessable (e.g. abandoned roads, trails, farm lane-ways, railroad berms etc.).

Physical features of the river valley (e.g. ponds, meandering streams) may also be obtained, facilitating later field operations (e.g. - knowing there is a pond between two stations means a greatly increased time of travel). If aerial photos are not current for that area and if budget permits, a quick low level flight over the area taking your own pictures can be very useful.

2.2 STATION SELECTION

Factors in locating sampling stations

Many factors are involved in deciding the location of stations for water quality sampling. The factors include: objectives of the survey, accessibility to the stream, time of travel from waste source, mixing of wastes with stream, physical characteristics of stream (e.g. is location on a sharp bend in the river, upstream or downstream of a dam, in the middle of a large empoundment etc?), length of survey reach, and personnel and equipment availability.

Ideal sampling location
Multi-point sampling
Dye studies

An ideal sampling station is one which would yield the same concentration of parameter no matter where in the cross-section the sample is taken. However, immediately downstream of waste inputs, complete lateral mixing of wastes and stream water rarely exists, so samples should be collected at various locations across the stream. Sometimes vertical mixing does not occur necessitating vertical sampling. Ideally, samples should be collected at various locations and the concentration at each location multiplied by the fraction of flow at each location to give the total loading. Dye dispersion studies can be very helpful in establishing sampling points in a cross-section of stream.

Even in large streams where vertical and lateral mixing are complete, it is good practice to sample at quarter points in the cross-section. Samples should be collected from exactly the same location at each station. Multi-point sampling locations should be marked with paint (if on a bridge) or with poles driven into the streambed (if shallow enough) or with anchored floats in the stream.

Time of travel between stations should be approximately 2 hours (less for small streams, more for larger).

Sampling from edge of stream

Sampling from the edge of a stream should be avoided. If possible, a rowboat, motor boat or chest waders should be used to sample in midstream. However, if a sample must be collected from the river bank, select a location on the outside of a bend where the current flows along the bank. It should be noted, however, that greater dissolved oxygen fluctuations occur along the streambank than in midstream because of the increased aquatic growth and fluctuating water temperature. Suspended solids levels may also be greater along the outside bank because of scouring. Stations should be spaced far enough apart that changes in water quality are measureable, but not too far apart that too great a change in water quality has occured since the previous station.

Sample waste sources and tributaries
Indirect sampling of waste loading

All waste sources and tributaries should be sampled where they enter the stream and their volumes should be known. The mainstream should also be sampled immediately upstream of the waste source or tributary to properly assess the effects of that load on water quality. If direct sampling of the waste source or tributary is impossible, then the river should be sampled and gauged directly above the source and at an appropriate distance downstream (immediately downstream for gauging and after complete mixing for sampling). The differences between the downstream and upstream loadings can be attributed to the input.

Control samples

Control samples (upstream from waste sources) should be obtained for comparative purposes and as inputs to the dissolved oxygen balance equation.

2.3 STREAM CROSS-SECTIONS

Change in physical characteristics of stream

Cross-sections of the streambed should be obtained wherever there is a significant change in the physical characteristics of the stream channel.

These profiles are used for calculating the reaeration coefficients (k_a or k_2) for each different section of the stream. The data can also be used for calculating times of travel using the volume-displacement method.[1]

Stage heights

As mentioned in Section 1.3 - Preliminary Field Studies, to relate stage height to streamflow for calculating volumes at various flows and to aid in calculating k_2 rates at various flows, staff gauges should be installed at stations which are representative of that reach of river. Every time that the station is visited, the stage height should be recorded so a graph can be drawn up relating stage height to streamflow (a log-log relationship).

Methods of collecting cross-sectional data

Cross-sections may be obtained using a graduated pole, a weighted rope or a depth sounder. Stream widths must also be measured (using a tape, graduated rope or stadia and transit). The distances between cross-sections must also be obtained (from a map, by stadia or with a graduated rope).

If stream profiles must be known for flows greater than those under which the cross-sections were obtained, then the profiles should be continued up the streambank to the height required.

2.4 FLOWS

Obtain all necessary flow data

Flow information must be known when carrying out time of travel and dispersion studies, cross-sectioning and intensive sampling (particularly if the stream is to be computer modelled). For modelling purposes it is necessary to know the stream flows, tributary flows and the volumes of all waste inputs.

[1] See Section 2.5.2 Volume - Displacement

Streamflows may be obtained from the MOE regional hydrologist for rivers that are gauged by the Water Survey of Canada or the M.O.E. (either by continuously recording or staff gauges). If flow data are not available from this agency, it will be necessary to gauge the stream with a Price-type or Ott current meter. Flow data for the stream and major tributaries should be obtained at least once per day during the survey. STP and industrial wastewater flows can be obtained from the plant operators (usually in the form of continuous flow chart).

Daily flows
continuous flows

2.5 TIME OF TRAVEL STUDIES

Time of travel (ToT) data are a vital part of a water quality study. To determine inputs to Dissolved Oxygen (DOMOD) model, data must be plotted versus time of water passage from the waste input (e.g. k_d rates are calculated from BOD vs ToT graph, k_n rates from TKN vs ToT graph). Time of travel is an important consideration when selecting sampling station locations.[1]

Data plotted vs ToT

Time of travel data will not change unless some physical change is made to, or occurs naturally in, the stream (e.g. straightening ox-bows, installing dams etc). Varying densities of aquatic weed growths can change ToT values under similar flow conditions. ToT data however, may become useful years later in a follow-up study or if a spill occurs and time of passage to a down-stream water supply is needed to determine if protective measures are necessary at a water treatment plant.

Data rarely changes
Effect of heavy weed growths

[1] See Section 2.2 - Station Selection

Extrapolation at ToT data to low flows may result in erroneous values if data has not been collected over a reasonably large flow range that includes low streamflows.

Data collected over large flow range

Time of travel may be determined for river reaches by any one of three methods:

a) floats
b) volume-displacement method
c) tracers.

Time of travel determinations

2.5.1 FLOATS

Surface or weighted floats may be timed from one section to the next to determine time of travel. However, in small streams floats have a tendency to become stuck on tree limbs or other obstacles or to travel into eddy areas or be moved to the streambank by the river current. They must then be redeposited into the current. Floats are also greatly affected by wind action.

Floats

Oranges make very good floats as they move with only a small portion of their surfaces exposed to wind action. They are easily spotted because of their colour, and tend not to be entangled because of their spherical shape which allows them to rotate around obstacles.

Oranges

Because oranges are carried by surface currents that are faster than the average for the stream, the observed time of travel should be multiplied by a factor of about 1.2 to obtain the actual Time of Travel.

Correction factor

2.5.2 VOLUME-DISPLACEMENT

Frequent intervals
Obtain ToT
Correction factor

A more suitable method of determining time of travel is to measure the cross-sectional area of the stream at frequent intervals, thus determining the volume of the section. A theoretical time of travel can then be calculated by dividing by the streamflow. However, because the whole stream does not move as one mass, the ToT obtained by this method should be verified using dye tracer techniques at a few locations and a factor applied to determine the actual times of travel (usually about 0.8 times the calculated value).

2.5.3 TRACERS

Meters
Brine
Radioisotopes
Dye
Fluorometer

The most desirable method of determining times of travel is by means of tracers. An industrial discharge may contain an occassional release of some conservative constituent which may be traced downstream by sampling or with a meter (e.g. pH or conductivity). Brine may also be used but because it is heavier than water, proper mixing with the streamwater may not occur or it may simply settle to the bottom of the stream if it is slow moving. Radioisotopes will give good time of travel results, however, safety and public disapproval may preclude their use, especially where public water supplies are taken from the river downstream. Rhodamine WT dye (20% solution) available from Dupont of Canada Limited has been found to be the most suitable dye tracer for streams. It is bright red in colour and can be detected to about 3 parts per trillion using a fluorometer.[1]

[1] See Section 5.4 - Fluorometer

If an estimate of the time of travel can be made prior to the dye study, using average stream velocity and distance, much time (and possibly dye) can be saved by having a good idea when the dye will reach the downstream location.

Estimate time

Dye samples can be kept for several days without losing their fluorescence if they are kept away from sunlight (dark garbage bags make suitable storage containers).

Keep samples from sunlight

Automatic water samplers, timed to sample every 15 minutes are very useful for dye sampling. Their use will free staff for other work and will also permit night-time sampling for dye. Care, however, should be taken in keeping the samples out of sunlight while they are in the sampler.

Automatic complex for dye work

Dye samples can either be analysed by the MOE laboratories or in the field office using a fluorometer or a spectrophotometer.

Analyses

The ideal method of obtaining time of travel data using dye is to proceed a few hundred feet upstream from the first station, inject the dye (which has been mixed with water in a container to eliminate density differences), and collect samples at the first and each successive station - about one every minute at the first station starting from before the dye reaches the station until the dye mass is completely past the station. Proceed to the next station and repeat the sampling procedure. Sampling at downstream locations may be carried out at 10 to 15 minute intervals with increased frequency as the dye mass passes the point. The length of time to sample is ideally the length of time between the time of injection and the time the leading edge reaches the station. The time of

Ideal method of conducting time of travel using dye
Time of travel

passage is the time that the centroid[1] of the dye passes. This centroid may be calculated either graphically, by integration or with a program developed by the Water Modeling Section for the Munrose Statistician 1860 programmable calculator. Time of travel is the time required for the passage of the centroid of the dye mass from one station to the next.

Practical method

In practice however, the dye is normally injected at the first station and samples collected at the next station to obtain the dye concentration vs time graph from which the centroid of the dye mass may be calculated.

Several reaches timed with some dye slug

Several reaches may be timed using the same dye slug, however, it may happen that sampling at one location might not be finished before sampling must begin at the downstream location, so two crews may be necessary. A form similar to the one presented in Fig. 2.1 can be used to record time of travel data.

Amount of dye for injection

Many equations have been developed to aid in determining the amount of dye to be injected for a time of travel study. Experimentation is the only way that one can obtain a "feel" for the amount of dye to be used, however, an approximation can be made using the following equation:

$$D = \frac{.15\ QLC}{V}$$

where D = dose of dye in ml
Q = streamflow in cfs
L = length of reach in miles

[1]Centroid - centre of mass

TIME OF TRAVEL STUDY – WATER RESOURCES BRANCH

DATE _____ RIVER _____ PARTY _____

DYE INJECTED AT STA. _____ AT _____ am pm. SAMPLES COLLECTED AT STA. ___

Bottle Number	Time of day	Fluorometer reading & opening				Remarks
		30 x	10 x	3 x	1 x	

C = concentration of dye desired
at the end of the reach in ppb
(approximately 2 ppb for fluorometer or 10 ppb for visual detection)

and V = velocity of stream in fps

Dye samples may be diluted

Remember that too little dye used means wasted effort and too much means a very red river, perhaps concerning the local citizens. If too much dye is used and the fluorometer goes "off-scale", on the least sensitive reading, then dye samples may be diluted with river water before measuring their fluorescence.

Inform authorities of use of dye in river

An important point to remember when using dye in a stream is that the public will usually see the bright red colour near the point of injection and in most cases will telephone some agency to inform them of the "pollution". Consequently, before using any dye in the stream, inform the proper authorities (such as police, local municipalities, conservation authorities etc.) of its use, specifying that it is a vegetable dye in an alcohol base and is harmless to plants and animals in the concentrations used. Great care should be exercised when using the dye in a stream from which public water supplies are taken downstream. Although the dye will not harm them in the concentrations used, the public does not take too kindly to drinking pink water.

2.6 SAMPLE TRANSPORTATION

Refrigerate samples

Samples for chemical and bacteriological analyses should be transported to the laboratories as soon as possible following sampling; bacteriological samples must be refrigerated and shipped in a cooler if possible. Samples for BOD_5 analysis

should be kept cool. Laboratory personnel may request special handling of samples in the field in some cases (e.g. filtering soluble reactive phosphorus samples).

Methods of shipping

Samples can be transported to the lab by various means including: survey vehicle, train, transport company, air express or freight, bus parcel express (BPX), courier service or, in special cases, private plane. The transportation method employed will depend upon delivery schedules, distance from lab, and costs.

Shipping schedules

When investigating sample transportation ensure that a schedule of service is obtained and enquire about how long the samples must be at the shipping point before scheduled shipment time. Remember, one minute late for shipment usually means the samples will be a day later arriving at the laboratories. Ensure that there is door-to-door delivery of samples or arrange for their pickup. Let the lab know when the survey is being carried out, so they can be prepared to analyze the samples quickly.

2.7 FIELD NOTES

Card for each station

To aid in recording field data in intensive surveys, a separate card should be made up for each station and kept in a note book. Each card should clearly indicate the station number, its location and any special sampling instructions (Fig. 2.2a). The run number, time of day, DO and temperature and any notable remarks should be entered as the data are collected. (Fig. 2.2b)

WATER QUALITY STUDY

RIVER BASIN :	SAMPLED BY :
STREAM :	SAMPLING POINT :

LOCATION OF WATER SAMPLING STATION :

SKETCH OF LOCATION :

ANALYSIS :

	5 DAY BOD	NITROGENS	– FREE AMMONIA
SOLIDS	– TOTAL		– TOTAL KJELDAHL
	– SUSPENDED		– NITRITE
	CONDUCTIVITY		– NITRATE
	TURBIDITY		CHLORIDES
PHOSPHORUS	– TOTAL		
	– SOLUBLE		

FIGURE 2·2a – FIELD DATA CARD (FRONT)

FIELD DATA

DATE OF SAMPLE D M Y	TIME OF DAY	WATER TEMP. °C	D.O. PPM	REMARKS (FLOW, WEATHER, ETC.)

2.8 SAMPLE NUMBERING

Clearly label samples

It is very important to clearly label samples to identify the exact time and place the sample was taken.

Assign numbers
Number change may result in confusion

Station locations should be assigned numbers starting from upstream of the waste source and proceeding downstream through the survey area. It is good practice to label stations prior to the preliminary work and to not change these station numbers after the start of data collection. Any change in numbering could later lead to confusion in applying preliminary data to final data and perhaps might lead to data being applied to the wrong station. If there may be a chance of adding stations later, label the original stations by two's (e.g. 2,4,6 etc.). Stream stations should be preceeded by a letter to identify the stream (eg. G8 is Station 8 on the Grand River).

Tributary labelling

To avoid confusion when interpreting data it is good practice to label tributaries with the prefix "T" in sequence with river stations. (e.g. GT39 would be a tributary entering the Grand River between river stations 38 and 40).

STP and industrial effluent numbering

STP and industrial effluents should be clearly labelled as such so the laboratory will recognize these samples and be able to give them special attention.

Multi-point sample numbering

If there is more than one sampling point at a location, number the points A, B, C, etc. (or L, C, R) from left to right side of the stream facing upstream.

Station-time

There are several good methods of labelling bottles in a water quality/assimilation study. One method utilizes station number and time of day. e.g. G18-1418 is Station 18 on the Grand River sampled at time 1418.

Station - run number

Since time of day and run numbers are being recorded in the notebook, another method is to indicate the station number followed by the run number e.g. G18-6 is station 18 sampled on run number 6. The time of run number 6 is recorded in the field note-book. This labelling method is preferred as it is less work for the sampler.

3. WATER SAMPLING PROCEDURES

3.1 CHEMICAL

Special handling

Special methods of handling or sample preparation are contained in the MOE Laboratory Service Branch publication "Outlines of Analytical Methods - 1975, M.O.E".

3.1.1 MANUAL

Directly
Bucket
Face Upstream
Avoid contamination

Samples should be collected, if possible, directly in the bottle submerged in the river. If sampling by immersing the bottle is not possible then the sample should be collected with a stainless steel, plastic or brass sampling apparatus and transferred to the bottle taking care not to contaminate the sample with the hands or with water from previous sampling. When sampling by hand (i.e. wading into the stream) the sampler should face upstream and grasp the bottle so the water coming into contact with the hands does not enter the bottle, thereby contaminating the sample. The bottle should be immersed below the water surface (except phenol samples which are skimmed from the surface, and samples for ammonium nitrogen analysis, which should not be bubbled) and the water should be allowed to overflow the bottle to ensure a representative sample.

3.1.2 AUTOMATIC

Not used for bacteriological or DO samples
Representative sample

Samples may be obtained using an automatic sampler[1] to where manpower is limited or access is poor. Automatic samplers should never be used to collect samples for bacteriological or DO analyses. The

[1] See Section 5.3.1 - Automatic Water Samplers

sampling hose should be placed in the main current on a stake or rod to obtain a representative sample and to allow the current to continuously cleanse the intake so the build-up of algae will be reduced on the intake. Samples should be removed daily.

3.2 BACTERIOLOGICAL

Avoid contamination

Bacteriological samples must be collected in sterilized bottles. If samples are obtained using a bucket, a bracket to hold the bottle to the outside of the bucket should be utilized. Care should be taken when handling the bottle to avoid contamination of the sample with the hands.

Depth sampling

Depth bacteriological samples should be obtained with a depth bacti sampler to avoid contamination from the sampling apparatus.

3.3 DISSOLVED OXYGEN (DO)

Prevent bubbling

When taking a water sample for DO analysis, care should be taken to ensure that there is no bubbling of water into the bucket. After the bucket is filled with water let it settle underwater for a few seconds to allow the river water to be exchanged, thereby ensuring that a representative sample is obtained. If possible, obtain the sample for DO analysis directly from the stream using the bottle in the DO field kit.

Care in collecting sample

When performing a wet chemical or Hach DO test, use the appropriate glass stoppered bottle. When taking the sample from a bucket, tilt the bottle as it is slowly lowered into the bucket, allowing the water to flow slowly down the sides of the bottle to avoid bubbling. After the bottle is

full of water, hold it under water for a few seconds to allow any small bubbles to escape. Then perform the DO analysis.

Meter
Agitate probe

When measuring DO with a meter, insert the probe directly into the river or sample bucket and gently agitate the probe (at the velocity of about 1cm/sec) to prevent oxygen depletion around the membrane. When the readings have stabilized, record the DO and temperature values. Take care to avoid banging the probe on rocks or the sides of the bucket as erratic readings will result.

Continuously recording DO meter
Minimize fouling by debris

When installing a DO meter for continuously recording DO, care should be taken to ensure that the probe is situated in the mainstream to avoid oxygen depletion around the membrane and to cleanse the probe. The probe can be suspended on a rod in the stream. Fouling of the probe by floating debris can be minimized by positioning a 1 ft. by 1 ft. mesh screen about 8 ft. upstream from the probe. This screen must be cleaned periodically.

Calibrating meter to Wet Winkler

When calibrating DO meters, 3 Wet Winkler DO determinations should be made and the values averaged. Do not agitate the probe if the meter is being installed for continuous recording of DO/Temperature, as this agitation will not occur in the stream after the installation is complete and erroneously low DO readings will result.

The Wet Winkler method of determining DO gives values in mg/l. Some meters must be calibrated in % Saturation.

Convert mg/l to % saturation

Table 3.1 shows saturation values of dissolved oxygen at various temperatures. To convert mg/l to % Saturation divide the measured DO value by the saturation value taken from Table 3.1 for the appropriate water temperature and multiply by 100.

TABLE 3.1 - Saturation Values of Dissolved Oxygen in Water at Different Water Temperatures (Under Normal Atmosphere at 760 mm. Pressure)

(Values in mg/l)

Temp (°C)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	14.62	14.58	14.54	14.50	14.46	14.42	14.39	14.35	14.31	14.27
1	14.23	14.19	14.15	14.11	14.07	14.03	14.00	13.96	13.92	13.88
2	13.84	13.80	13.77	13.73	13.70	13.66	13.62	13.59	13.55	13.52
3	13.48	13.44	13.41	13.38	13.34	13.30	13.27	13.24	13.20	13.16
4	13.13	13.10	13.06	13.03	13.00	12.97	12.93	12.90	12.87	12.83
5	12.80	12.77	12.74	12.70	12.67	12.64	12.61	12.58	12.54	12.51
6	12.48	12.45	12.42	12.39	12.36	12.32	12.29	12.26	12.23	12.20
7	12.17	12.14	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.90
8	11.87	11.84	11.81	11.79	11.76	11.73	11.70	11.67	11.65	11.62
9	11.59	11.56	11.54	11.51	11.49	11.46	11.43	11.41	11.38	11.36
10	11.33	11.31	11.28	11.25	11.23	11.21	11.18	11.15	11.13	11.11
11	11.08	11.06	11.03	11.00	10.98	10.96	10.93	10.90	10.88	10.86
12	10.83	10.81	10.78	10.76	10.74	10.71	10.69	10.67	10.65	10.62
13	10.60	10.58	10.55	10.53	10.51	10.48	10.46	10.44	10.42	10.39
14	10.37	10.35	10.33	10.30	10.28	10.26	10.24	10.22	10.19	10.17
15	10.15	10.13	10.11	10.09	10.07	10.05	10.03	10.01	9.99	9.97
16	9.95	9.93	9.91	9.89	9.87	9.85	9.82	9.80	9.78	9.76
17	9.74	9.72	9.70	9.68	9.66	9.64	9.62	9.60	9.58	9.56
18	9.54	9.52	9.50	9.48	9.46	9.44	9.43	9.41	9.39	9.37
19	9.35	9.33	9.31	9.30	9.28	9.26	9.24	9.22	9.21	9.19
20	9.17	9.15	9.13	9.12	9.10	9.08	9.06	9.04	9.03	9.01
21	8.99	8.98	8.96	8.94	8.93	8.91	8.89	8.88	8.86	8.85
22	8.83	8.81	8.80	8.78	8.77	8.75	8.74	8.72	8.71	8.69
23	8.68	8.66	8.65	8.63	8.62	8.60	8.59	8.57	8.56	8.54
24	8.53	8.51	8.50	8.48	8.47	8.45	8.44	8.42	8.41	8.39
25	8.38	8.36	8.35	8.33	8.32	8.30	8.28	8.27	8.25	8.24
26	8.22	8.20	8.19	8.17	8.16	8.14	8.13	8.11	8.10	8.08
27	8.07	8.05	8.04	8.02	8.01	7.99	7.98	7.96	7.95	7.93
28	7.92	7.90	7.89	7.87	7.86	7.84	7.83	7.81	7.80	7.78
29	7.77	7.75	7.74	7.73	7.71	7.70	7.69	7.67	7.66	7.64
30	7.63									

e.g. Wet Winkler value - 9.6 @ 14.8°C

$$\% \text{ saturation} = \frac{9.6}{10.19} \times 100 = 94.2\%$$

Adjust for differences in elevation

DO readings must be adjusted for differences in elevation (actually differences in atmospheric pressure[1]) according to Table 3.2.

Table 3.2 - Dissolved Oxygen Correction Factors for Varying Altitudes

ATMOSPHERIC PRESSURE (mm Hg)	EQUIVALENT ALTITUDE (Ft. above sea level)	Correction Factor
760	0	1.00
	270	.99
745	542	.98
	818	.97
730	1094	.96
	1390	.95
714	1688	.94
	1980	.93
699	2274	.92

e.g. if the previous DO value of 94.2% were determined at a elevation of about 1100 ft. above sea level, the actual DO reading would be 94.2 x .96 = 90.4%.

3.4 20 DAY BOD (for K_1 Rate)

At first station downstream from discharge
Near end of survey reach

A 20 day incubation test is performed to determine the relationship between BOD_5 and the ultimate BOD of the streamwater. Samples for incubation tests should be taken at the first station downstream from the waste discharge where complete mixing of the waste and stream water has taken place. If possible, samples for another 20 day BOD test should also be taken in the effluent and also near the downstream end of the survey reach.

[1] May be obtained from nearby meteorological station e.g. airports

A total of 12-1 litre bottles should be taken at each site and all numbered identically. The lab submission sheet should be labelled "For K_1 Analysis - complete nitrogen analyses to be performed on the incubated sample on days 0, 5, 10, 15 and 20 days". The nitrogen analyses are performed concurrently to establish a true K_1 attributable to carbonaceous BOD (CBOD).

Number of bottles
Sample labelling
Nitrogens in parallel

Appropriate staff at the lab should be notified prior to submission of the samples to enable them to prepare for the analyses.

Notify lab

3.5 BOD_5 WITH NITROGENS IN PARALLEL

To determine the portion of the BOD_5 (as opposed to ultimate BOD) that is actually carbonaceous, 5 day BOD analyses, with complete nitrogen analyses on the first and fifth days, should be taken at least three times at all stations. The difference between the total BOD_5 and the BOD attributable to nitrogens is the carbonaceous BOD_5 (CBOD) which is used to calculate the true CBOD loadings from which a true L_0 and k_d can be calculated. It should be stressed that the NOD reaction obtained from the above analysis is not the actual NOD reaction rate in the stream but only that which was measured in the bottle. The actual coefficient of nitrogenous deoxygenation (k_n) is determined from the degradation of nitrogens in the stream from station to station and is probably much higher than that which is measured in the bottle.

Carbonaceous and nitrogenous BOD

3.6 SPECIAL SAMPLING TECHNIQUES AND HANDLING OF SAMPLES

"Outlines of Analytical Methods, 1975, M.O.E." outlines special handling techniques, perishability of samples, preservation techniques, special

Laboratory Services booklet

sample containers, volumes of sample required, analytical technique for analysis and special handling of samples.

3.6.1 INPUT SAMPLING

Effect of chlorine Sample prior to chlorination

One of the most important samples collected during an assimilation study is from the final effluent of an STP or industrial plant. This effluent often contains residual chlorine for disinfection purposes. Chlorine is a strong oxidizing agent which inhibits the BOD test. Although the chlorine may be eliminated by the addition of the proper amount of sodium thiosulphate, the titration procedure is somewhat complicated to perform in the field. It is therefore very important that all samples of final effluents be taken prior to chlorination to ensure a representative BOD_5 concentration.

Bacti sampling

Bacteriological samples should be taken in bottles specially prepared by the MOE labs for sampling water with chlorine present.

Sample upstream and downstream from inputs

It is wise to obtain a good number of samples[1] of the final effluent, as the BOD_5 and nutrient levels form a very important input to the dissolved oxygen model. It is also a good idea to obtain samples directly upstream from the inputs (including tributaries) and after complete mixing of the stream with the input as a check on your input loading (using mass balance equation[2]).

[1] Twelve samples provide statistical reliable data

[2] $C_u Q_u + C_I Q_I = C_D Q_D$

C = concentration
Q = flow
u = upstream
I = input
D = downstream

3.6.2 SAMPLING FOR AMMONIUM NITROGEN

Minimize bubbling
Kemmerer sampler
Wide-mouthed bottle

As ammonia gas is released by bubbling action (or converted to other forms of nitrogen) care should be taken to minimize bubbling of the sample for ammonium nitrogen analysis. This may be accomplished by special sampling devices (such as a kemmerer sampler) which can be used to obtain a representative sample below the surface of the water, special pumps which will not bubble the sample, or by carefully obtaining a sample from the surface of the water by allowing the water to gently flow down the sides of the bottle. Wide-mouthed bottles can best be used to sample by this method.

4. PRELIMINARY DATA COMPILATION

Chemical, bacteriological and dissolved oxygen/ temperature data can be recorded and summarized on cards similar to that presented in Figure 4.1. Data from these cards are then used to construct graphs of DO vs Time of Day at each station (Fig. 4.2), BOD_5 vs Time of Travel (Fig 4.3a), and Nitrogens vs Time of Travel (Fig 4.4).

Data summaries
Graphs

From the BOD_5 vs ToT graph, the coefficient of BOD removal (k_r) and the coefficient of deoxygenation (k_d) are calculated (Fig. 4.3b). To accurately determine the break between k_r and k_d, a graph of Volatile Suspended Solids (VSS) vs Time of Travel can be drawn up (Fig. 4.3c).

k_r
k_d
VSS

The rate of nitrogenous oxygen demand (k_n) is calculated from the Total Kjeldahl Nitrogen (TKN) vs Time of Travel graph.

k_n

The methods of calculating k_r, k_d and k_n are contained in the Water Modelling Stream Seminar Handbook (WMS, WRB-1975).

Twenty-day BOD rates (K_1) are calculated by the laboratory section and the final result forwarded to the requesting party.

K_1

Graphs of Flow vs Time of Travel should be prepared (Fig. 4.5). If data has been collected over a large streamflow range then interpolation and limited extrapolation can be reliably carried out.

Flows vs ToT

Cross-sectional areas of the stream are used in the volume-displacement method of determining time of travel using the following relationship:

Volume-displacement

Ministry of the Environment

Stream ..... Station ..... Description .....

DATE	D.O. (mg/l)	Temp °C	BOD5 (mg/l)	Bacteria / 100 ml			Phosphorus		Nitrogens									
				T.C.	F.C.	F.S.	Total	Sol.	F.A.	Kjel	Nitrite	Nitrate						
AVERAGE																		
MAXIMUM																		
MINIMUM																		
STAND. DEV.																		

FIGURE 4·1 — MONITOR DATA CARD

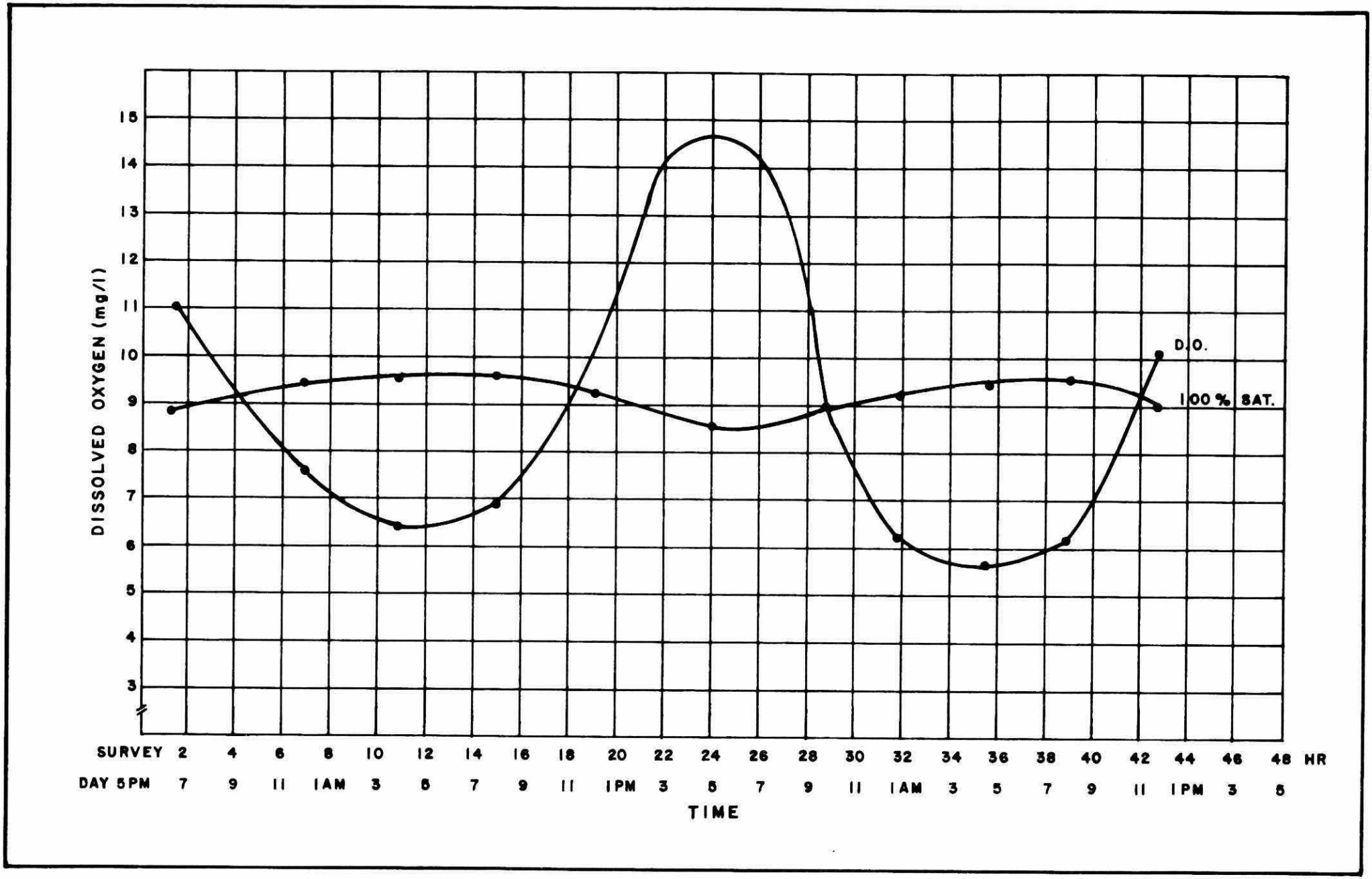

FIGURE 4·2 — DISSOLVED OXYGEN Vs TIME OF DAY GRAPH (GRAND RIVER D/S WATERLOO)

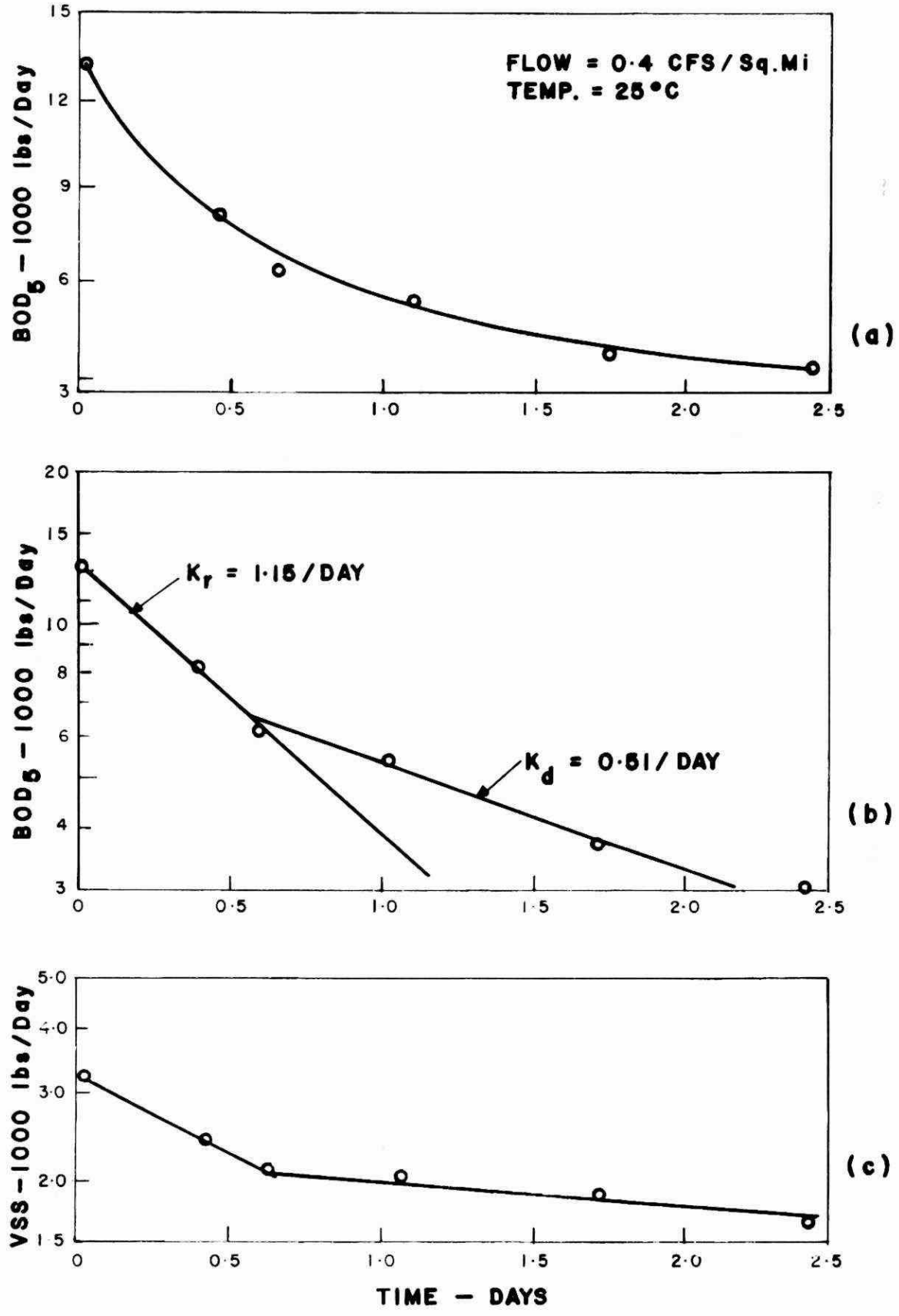

FIGURE 4·3 – a) BOD_5 , b) Log BOD_5 , c) VSS Vs TIME OF TRAVEL

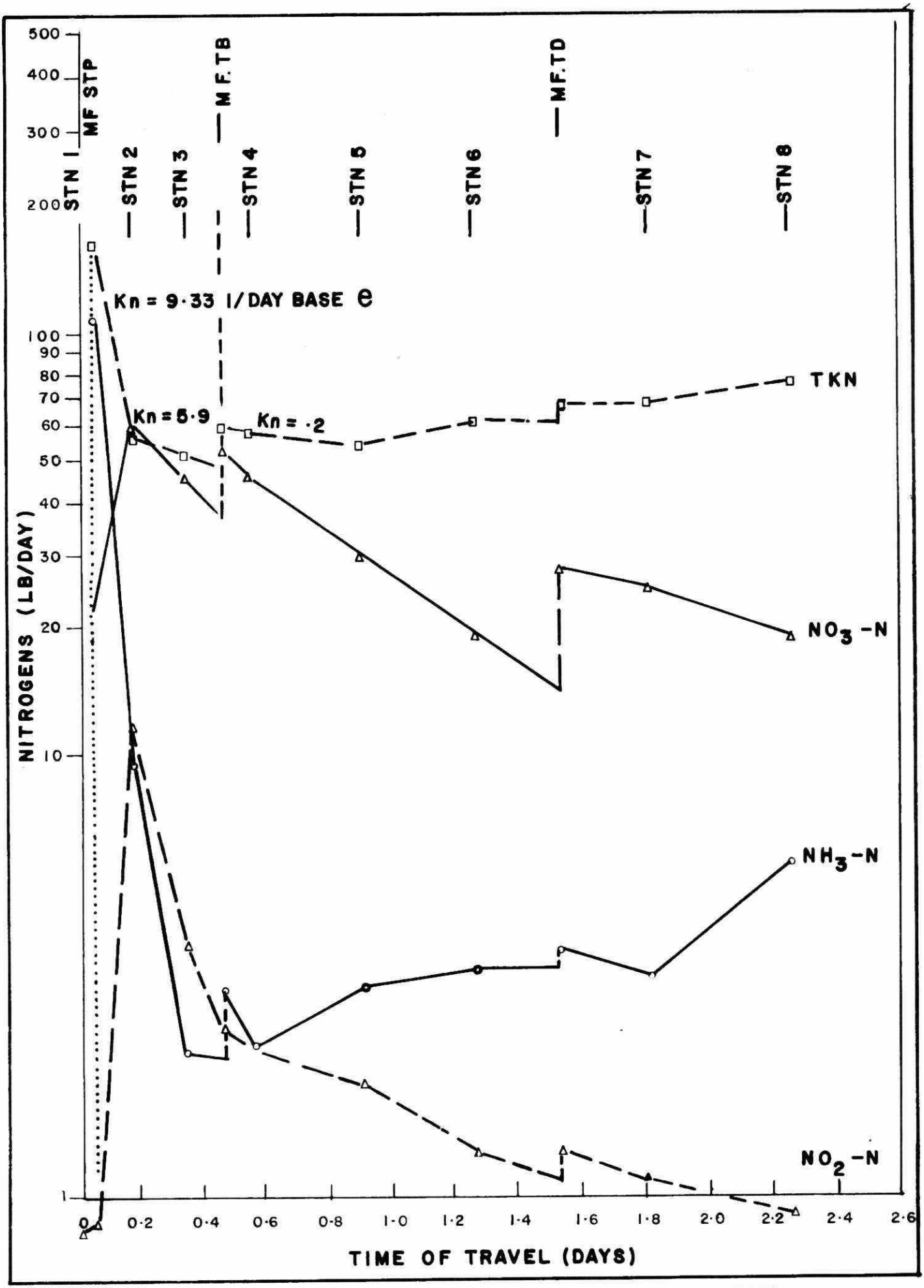

FIGURE 4·4 — NITROGENS Vs TIME OF TRAVEL
(S. SAUGEEN RIVER D/S MOUNT FOREST ONTARIO)

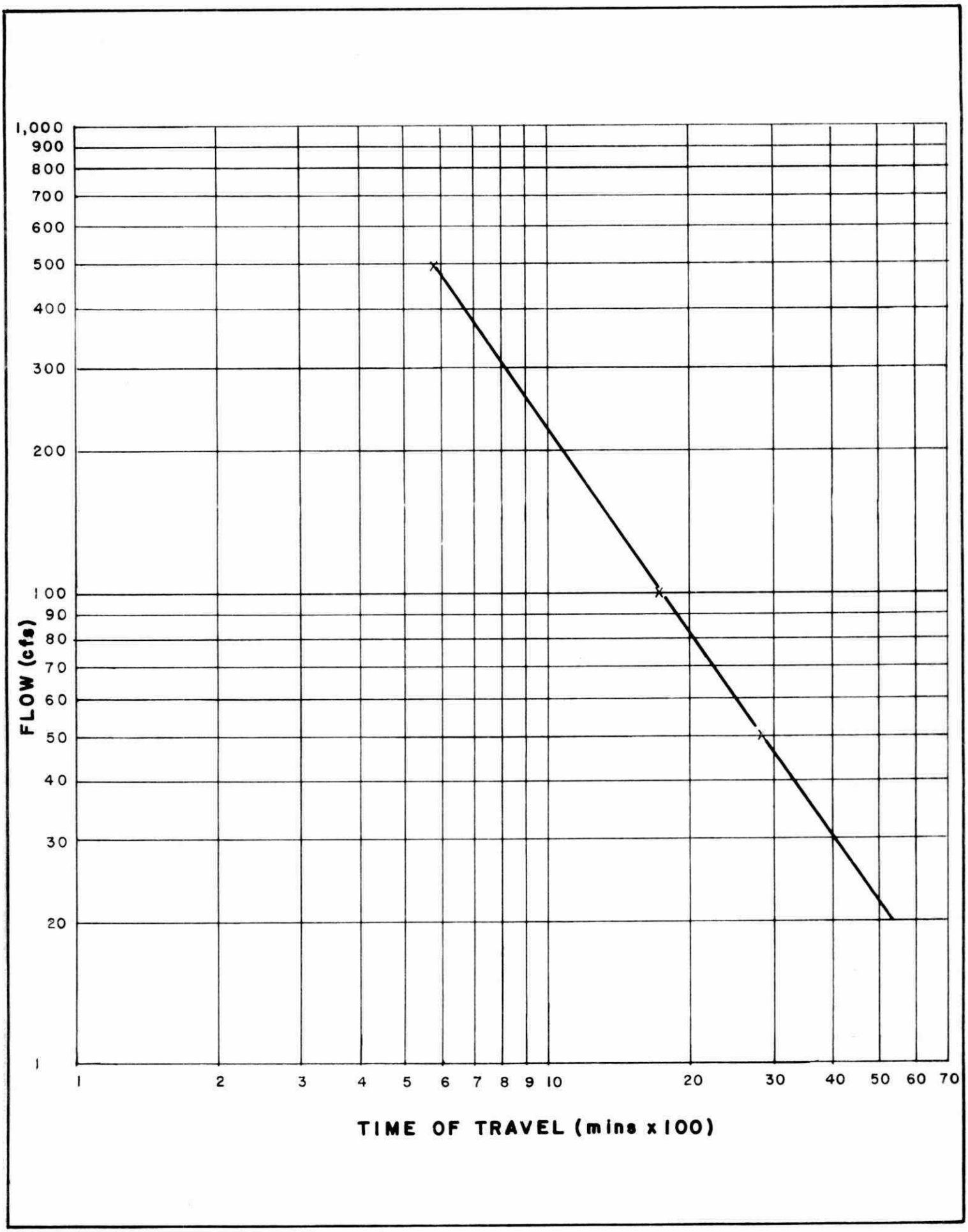

FIGURE 4·5 — FLOW Vs TIME OF TRAVEL GRAPH
(SPEED RIVER D/S GUELPH)

$$Q = AV$$

$$= \frac{AL}{t}$$

or $$t = \frac{AL}{Q}$$

where t = time of travel in seconds

A = cross sectional area of reach in square feet (ft^2)

L = length of reach in ft

Q = streamflow in cubic ft per second (cfs)

V = Velocity of stream in feet per second (fps)

The coefficients of reaeration (k_a or k_2) are also calculated from the cross-sectional data using the formula:

Coefficient of Reaeration (k_2)

$$k_2 = \frac{13 \times V^{\frac{1}{2}}}{H^{3/2}}$$

k_2 is coefficient of reaeration (1/day)

V is velocity of stream in ft/sec

H is average depth of stream in ft

Methods of calibrating cross-sectional areas

Cross-sectional areas may be calculated from field data by graphical means (area using squared paper), planimeter, or by Simpsons Rule for calculating areas. Water Modelling Section has developed a program for the Munroe 1860 calculator for calculating areas, mean depths and volumes from cross-sectional data.

5. EQUIPMENT

5.1 WATER SAMPLING

5.1.1 BUCKETS

Bucket material

Sampling buckets should be made from relatively non-contaminating materials such as stainless steel or plastic (e.g. PVC). However, care should be taken when sampling for certain parameters that the bucket material does not contaminate the sample. The sampling bracket should always be rinsed thoroughly before taking the sample.

5.1.2 DEPTH SAMPLERS

Various types of samplers can be used to sample water from depths. These are made from brass, PVC or acrylic; some are nickel-plated or teflon-lined to virtually eliminate chance of sample contamination.

Avoid damage to sampler

Some depth samplers (such as Kemmerer samplers) are suitable for sampling from bridges. However, care should be taken to reduce the speed of descent of the messenger while above the water's surface (by waving the line) to prevent damage to the sampler, or even its loss by breaking the line as the messenger hits the trigger mechanism.

5.1.3 AUTOMATIC WATER SAMPLERS

There are many automatic water samplers on the market. Which type of sampler to purchase depends on its application, features and cost. Some of the items to consider when choosing an automatic water sampler are:

- portability (weight)
- power requirements (A.C., D.C. or vacuum operated)
- type of sample obtained - composite
  - discrete
- type of sample container (glass or plastic)
- amount of sample obtained (is it sufficient for analyses required?)
- is sampling to be proportional to flow?
- can samples be refrigerated within the unit?
- is there any possibility of cross-contamination of samples?
- are materials with which the sample comes in contact corrosion proof and easily cleaned?
- simplicity of operation
- durability
- does it have pre-sample purge cycle to reduce chance of contamination from previous sample and to cleanse the hose end of any accumulated debris?
- sampling velocity - a too slow sampling velocity allows suspended solids to settle out; a too fast sampling velocity could pick up bottom sediments

5.2 DO METERS

Electronic DO meters considerably reduce the manpower required to perform DO tests.

Polarographic probe

Two different types of electrodes are used in DO meters. The POLAROGRAPHIC type consists of a noble metal cathode and a solid noble metal anode (e.g. YSI Model 54-gold cathode, silver anode).

The other type of electrode is the GALVANIC type with a noble metal cathode and a decomposable anode (e.g. EIL 1510 - silver cathode, lead anode). Membranes are more difficult to change than on the polarographic type. Anodes are consumable and must be replaced about every six months in normal use.

Galvanic probe

YSI DO meters are automatically temperature compensated, read directly in "mg/l" and are light and easy to transport and store. It is, however, difficult to continuously record data from these meters as the output signal is not compatable with reasonably priced recorders.

YSI DO meter

The EIL 1510 is bulkier than the YS154 meter, however, a Rustrak Model 288 DC recorders may be plugged directly into the meter facilitating continuous recording of DO and temperature. This meter measures DO in % sat. and the DO readings are temperature compensated.

EIL DO meter

To save effort and reduce chance of errors, one should consider only temperature compensated models when purchasing DO meters. (Additional features such as salinity compensation are of little value in normal surface water studies in Ontario).

Temperature compensation
Salinity compensation

5.3 BENTHIC RESPIROMETER

The Water Resources Branch has developed a respirometer which permits measuring "in situ" oxygen uptake of benthic deposits by passing streamwater over a benthic deposit for several hours. The oxygen utilized by the benthic deposits is then calculated and expressed in $gmO_2/m^2/day$. The benthic oxygen uptake rate (sludge demand) is a dissolved oxygen "sink" in the dissolved oxygen balance equation.

"In situ" benthic demand test

5.4 FLUOROMETER

Measures flourescence of water from dye
G. K. Turner Model III
Turner Designs

Rhodamine WT dye, used in time of travel, effluent dispersion and flow measuring studies may be detected in the stream using a fluorometer with filters which measure the appropriate wavelength of fluorescence. Fluorometers are usually portable and may be powered in the field by a small A. C. generator. With a high sensitivity door G. K. Turner Model 111 fluormeter can measure fluorescence to about .05 parts per billion (ppb). Optional equipment for this instrument includes a flow-through door, a constant temperature door, and a recorder. A more sophisticated fluorometer, made by Turner Designs, measures fluorescence to about 3 parts per trillion and automatically drops to a more sensitive range when the detection limit of that range is reached. This instrument will operate from a 12 volt wet-cell battery and is a very rugged piece of field equipment. The fluorometer should be calibrated before each use.

5.5 PYRANOGRAPH

Measures sunlight intensity

This portable instrument measures and records solar radiation in gm cal/cm^2/min, for either a 24 hour or 7-day period. The recorded data will provide the time of sunrise and sunset and the intensity of sunlight for that day. This information is necessary for input to the dissolved-oxygen balance equation when modelling for photosynthesis and respiration.

5.6 DEPTH SOUNDER

Measures stream depths

This equipment is useful for determining the cross-sectional area of the stream. The data is used in k_a (k_2) calculations and time of travel calculations in large rivers. Some points to consider when purchasing a depth sounder are:-

Points to consider when purchasing sounder

- chart speed (the faster the better)
- printout - perpendicular printout rather than circular to prevent distortion of recording
- ensure that scale provides adequate profiles at shallow depths
- portability
- accuracy
- precision
- durability
- splash proof case

5.7 CURRENT METER

Types of current meters

If flows must be obtained manually a suitable current meter such as a Price-type Gurley Current Meter No. 622 or an Ott type C31 should be used. When gauging smaller streams a small cup Pigmy meter should be used with the Gurley Meter.

ABBREVIATIONS

BOD	-	Biochemical Oxygen Demand
^{o}C	-	degrees centigrade (celsius)
CBOD	-	Carbonaceous Biochemical Oxygen Demand
cm	-	centimetre(s)
DO	-	Dissolved Oxygen
D/S	-	Downstream
ft	-	foot (feet)
gm cal/cm^2/min	-	gram calories per square centimetre per minute
in	-	inch(es)
K_1	-	laboratory rate of BOD stabilization
k_2 or k_a	-	coefficient of atmospheric reaeration (day^{-1})
k_d	-	coefficient of carbonaceous deoxygenation (day^{-1})
k_n	-	coefficient of nitrogeneous deoxygenation (day^{-1})
k_r	-	coefficient of BOD removal (day^{-1})
mg/l	-	milligram(s) per litre
NOD	-	Nitrogeneous Oxygen Demand
oz	-	ounce(s)
ppb	-	parts per billion
ppm	-	parts per million
P&R	-	Photosynthesis and Respiration (modelling)
STP	-	Sewage Treatment Plant
ToT	-	Time of Travel
TKN	-	Total Kjeldahl Nitrogen
U/S	-	Upstream
VSS	-	Volatile Suspended Solids

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